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(54) Method and device for determining a measurement for color control in a printing process

(57) A method and device for evaluating a printing process which can be used for determining a measurement to be exercised for control of the printing process, the method comprising the steps of (a) calculating a multidimensional data representation of a reference image; and (b) clustering the multidimensional data representation into at least one cluster of data according to at least one multidimensional clustering algorithm, each of the at least one clusters of data being for determining at least one feature of measurement of the reference image, the device comprising calculating means and clustering means for effecting these steps, wherein the at least one feature of measurement is for selecting at least one type of physical measurement to be performed on a printed image for a color based control of the printing process of the printed image.

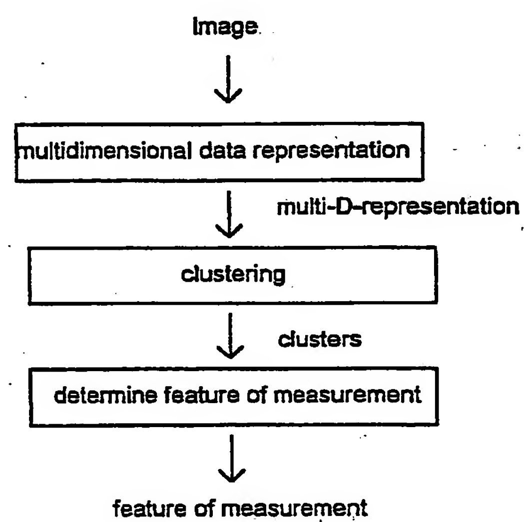

FIG. 1

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of data according to at least one multidimensional clustering algorithm, each of the at least one clusters of data being for determining at least one feature of measurement of the reference image, the at least one feature of measurement being for selecting at least one type of physical measurement to be performed on a printed image, the at least one type of physical measurement being for a color based control of the printing process of the printed image.

According to still further features in the described preferred embodiments the device further comprising (c) a measuring apparatus for performing the at least one type of physical measurement for obtaining at least one physical measure of the printed image and for determining whether the at least one physical measure being within a predetermined range.

According to still further features in the described preferred embodiments the device further comprising (d) a feedback system for adjusting the printing process if the at least one physical measure is out of the predetermined range.

According to still further features in the described preferred embodiments the device further comprising (d) an alarm system for actuating an alarm signal if the at least one physical measure is out of the predetermined range.

According to still further features in the described preferred embodiments the device further comprising (d) a recording system for recording the physical measure for producing a report.

According to still further features in the described preferred embodiments the device further comprising (d) communication means for communicating the feature of measurement to a distant printing station.

According to still further features in the described preferred embodiments the reference image and the printed image are a single image.

According to still further features in the described preferred embodiments the reference image is selected from the group consisting of a prepress digital image and an acquired image.

According to still further features in the described preferred embodiments the multidimensional data representation is a multidimensional histogram.

According to still further features in the described preferred embodiments the calculation of the multidimensional data representation is according to at least two dimensions, of which at least one is a spatial coordinate, and at least one is a color dimension of a color space.

According to still further features in the described preferred embodiments the calculation of the multidimensional data representation is further according to a time dimension.

According to still further features in the described preferred embodiments the calculation of the multidimensional data representation is according to at least two dimensions selected from the group consisting of a first spatial coordinate, a second spatial coordinate, an angle, a red color dimension, a green color dimension, a blue color dimension, a cyan color dimension, a magenta color dimension, a yellow color dimension, a black color dimension, an L* color dimension, an a* color dimension, a b* color dimension, an X color dimension, a Y color dimension, a Z color dimension, a L color dimension, a U color dimension, a V color dimension and a time dimension.

According to still further features in the described preferred embodiments the at least two dimensions include at least one dimension of a spatial coordinate selected from the first and second spatial coordinates and at least one dimension selected from the color dimension.

According to still further features in the described preferred embodiments the clustering of the at least one cluster of data is effected by at least one multidimensional clustering weighting function, each of the at least one multidimensional clustering weighting functions has a predetermined range in each of the dimensions, the clustering is according to at least one rule.

According to still further features in the described preferred embodiments the at least one multidimensional clustering algorithm is selected from the group consisting of a simple cluster seeking algorithm, a maximin distance algorithm, a K-means algorithm and an isodata algorithm.

According to still further features in the described preferred embodiments the at least one feature of measurement is selected from the group consisting of a measurement for determining the presence and value of at least one color in at least one given location in the reference image and a measurement for determining at least one location of at least one given color in the reference image.

According to still further features in the described preferred embodiments the at least one type of physical measurement is selected from the group consisting of a measurement for determining the presence and value of at least one color in at least one given location in the printed image and a measurement for determining at least one location of at least one given color in the printed image.

The present invention successfully addresses the shortcomings of the presently known configurations by providing a method and device for determining a measurement to be exercised for control of a printing process, which method and device are directed at defining feature of measurements in an inventive way never proposed before, which way is highly versatile, employing multiple dimensions defining printed images and are therefore applicable for numerous applications.

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binary histogram (i.e., each of the cells is attributed a value selected from zero and one). Therefore, quantization is preferably performed in all/some of the histogram dimensions, to obtain a non-binary histogram, to lower the amount of computer memory required to store the data and to lower the amount of time required for computer processing.

One example of quantization may be having X and/or Y dimensions given in groups of 10 pixels resolution, and/or having one or more of the RGB color dimensions given in 10 gray level steps.

Furthermore, a small portion of the image may be used to create the histogram instead of using the entire image. In all cases the histogram is calculated by assigning each cell within the histogram the number of pixels within the original image, which falls within the cell's XYRGB coordinates, after quantization.

Likewise a 4D histogram may be created using for example only the XRGB dimensions. In this case the histogram depends only on X spatial dimension, therefore histogram values correspond to stripes along the Y spatial dimension. Hence, in this case the X dimension may be quantized to match operation zones of various inking adjusting means used in various presses (e.g., ink-keys used in offset presses), and thus to regulate each of the inking adjusting means within its corresponding printing zone.

It will be appreciated by one ordinarily skilled in the art that any other combination of at least two dimensions may be similarly used for histograming as described.

In cases where the spatial and/or color resolutions are less than as described above, multidimensional data representation may be selected as a multidimensional binary function such as f(X,Y,R,G,B), etc., for obtaining a binary histogram. In this case no quantization as described above is required.

In a preferred embodiment clustering the multidimensional data representation, e.g., creating the multidimensional histogram, into clusters of data is effected by a multidimensional clustering weighting function such as for example a window clustering function, which has a predetermined range in each of the dimensions used, the clustering is effected according to at least one rule.

The predetermined range in any of the dimensions may be selected to be tolerances (i.e., deviations) from desired nominal measurements of color values and/or spatial values. Tolerances may be selected maximal or minimal for any of the spatial and/or color dimensions.

As far as color dimensions are of concern, any user defined distance between two spectrum functions, such as correlation coefficient, sum of squares of difference between spectrum corresponding components or any other distance function known in the art, may be used to determine the predetermined range in any of the color dimensions.

With reference now to Figure 2, presented is a flow diagram of a preferred clustering algorithm according to the present invention. Preferred clustering steps are boxed. As shown in Figure 2, the input to the preferred clustering algorithm is a multidimensional histogram, e.g., a 5D-(X,Y,R,G,B)-histogram (equation 1):

$$H(X,Y,R,G,B) \tag{1}$$

The window function employed for clustering may acquire a form of any shape, such as but not limited to a sphere, an ellipsoid, a cylinder, a hyper cube, a multidimensional exponential decaying window, etc., and is defined herein as (equation 2):

$$W(X,Y,R,G,B) \tag{2}$$

A preferred example of a 5D window is given in equation 3:

$$W(X,Y,R,G,B) = C \cdot e^{-\frac{1}{2}\left[\frac{X^2}{T_X}+\frac{Y^2}{T_Y}+\frac{R^2}{T_R}+\frac{G^2}{T_G}+\frac{B^2}{T_B}\right]} \tag{3}$$

wherein, C is a constant and T_X, T_Y, T_R, T_G and T_B determine the allowable deviation of cluster component values from the cluster's central value.

After selecting a suitable window function, a correlation with the window function is performed according to equation 4:

$$\Upsilon(X,Y,R,G,B) = \sum_{X'}\sum_{Y'}\sum_{R'}\sum_{G'}\sum_{B'} H(X',Y',R',G',B') \cdot W(X-X',Y-Y',R-R',G-G',B-B') \tag{4}$$

wherein $\Upsilon(X,Y,R,G,B)$ is the correlation and X', Y', R', G', B' are all possible dimension coordinates of the cells of the histogram.

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algorithm and an isodata algorithm, all as described in J.T. Tou and R.C. Gonzalez (1974) Pattern recognition principles. Addison-Wesley publishing company, Reading MA. pp. 75-108, which is incorporated by reference as if fully set forth herein, and clustering algorithms described in T.Y. Young and K.S. Fu (1986) Handbook of pattern recognition and image processing. Academic Press Inc. San Diego CA, pp. 33-57, which is incorporated by reference as if fully set forth herein.

As mentioned above, the method according to the present invention is directed at providing a feature of measurement regarding an image for color based control of the printing process employed for printing the image, wherein providing the feature of measurement is by calculating a multidimensional data representation of the image (e.g., by histograming), clustering the multidimensional data representation of the image into at least one cluster of data according to a multidimensional clustering algorithm and using the clusters of data for determining the feature of measurement of the image.

The term feature of measurement as used herein in this document and especially in the claims section below refers to a description of any type of actual (i.e., physical measurement) that can be or is performed on an image. Basically two types of measurements can be performed on an image for color control, these include (i) a measurement for determining the presence and value of at least one color in at least one given location in the image; and (ii) a measurement for determining at least one location of at least one given color in the image, according to the first option a location is given and the measurement is of a color, whereas according to the second, a color is determined and the measurement is of a location. As is clear to one skilled in the art, the first option is more prominent for color control.

Examples of feature of measurements according to the present invention include but are not limited to (i) desired measurement of color(s) and/or color(s) tolerance(s); (ii) measurement of location(s) and/or location(s) tolerance(s); (iii) a suggested sequence of measurements of locations and/or colors; (iv) randomization of sequence of measurements of locations.

An example of providing a feature of measurement using a single 5D(XYRGB) cluster includes: (i) taking a desired nominal color value as the average color value of cells within the cluster; (ii) taking the tolerance for the desired nominal color value as the standard deviation of the color value, of the cells within the cluster, from the desired nominal color value; (iii) repeatedly taking measurement of locations as the spatial (i.e., X, Y) coordinates of histogram cells within the cluster, wherein cells are randomly selected from the group of histogram cells within the cluster.

A similar process may be applied to a group of clusters .For example, where each cluster corresponds to a different color value, one can use clusters consecutively in order to examine different colors of interest at random locations.

The physical measurement may be the spectrum of reflected illumination as determined by a spectrometer, the density as determined by a densitometer; the color as determined by a colorimeter; or color and density in respect to spatial locations as determined by acquiring an image using a camera (e.g., array CCD, line CCD, etc.).

The method according to the present invention is directed at providing a feature of measurement regarding an image for color based control of the printing process employed for printing the image. The determined feature of measurement may thereafter be used for selecting a physical measurement to be performed on the image and used for a color based control of the printing process employed to print the image.

Thus, further according to the method of the present invention a physical measurement for obtaining a physical measure of the image is performed and whether the measured physical measure is within a predetermined range is determined. This determination may be used for various purposes such as for example (i) adjusting the printing process if the physical measure is out of the predetermined range; (ii) actuating an alarm signal if the physical measure is out of the predetermined range; (iii) recording the physical measure for producing a printing quality report.

In a preferred embodiment the method according to the present invention includes (a) calculating a multidimensional data representation of a reference image; and (b) clustering the multidimensional data representation into at least one cluster of data according to at least one multidimensional clustering algorithm. Each of the at least one clusters of data is for determining at least one feature of measurement of the reference image for selecting at least one type of physical measurement to be performed on a printed image for a color based control of the printing process of the printed image.

The reference image and/or the printed image may be a digital image corresponding to a printed substrate. Source of the reference image may be a prepress image, an image acquired during start of press, an image acquired any time during press, a digital image supplied trough network, disk, reference image may be created using array CCD camera, linear CCD camera, or created using any computing means, such as but not limited to a computer, e.g., the international business machine by IBM or a compatible personal computer having a CPU such as the Intel pentium pro CPU. In another embodiment the reference image and the printed image are a single image.

In a preferred embodiment, the feature of measurement may be communicated to a distant printing station, via any data communication means such as, but not limited to electronic mail (Email). This would assist for example in the news paper industry, since in many cases printing is performed in a distant country.

With reference now to Figure 3, further according to the invention provided is a device for effecting the various embodiments of the method described hereinabove. The device, generally referred to as device **10** is for evaluating a printing process, and includes (a) calculating means **12** for calculating a multidimensional data representation of a ref-

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(a) calculating a multidimensional data representation of a reference image; and

(b) clustering said multidimensional data representation into at least one cluster of data according to at least one multidimensional clustering algorithm, each of said at least one clusters of data being for determining at least one feature of measurement of said reference image, said at least one feature of measurement being for selecting at least one type of physical measurement to be performed on a printed image, said at least one type of physical measurement being for a color based control of the printing process of said printed image.

2. A method as in claim 1, further comprising the steps of:

(c) performing said at least one type of physical measurement for obtaining at least one physical measure of said printed image; and

(d) determining whether said at least one physical measure being within a predetermined range.

3. A method as in claim 2, further comprising the step of:

(e) adjusting the printing process if said at least one physical measure is out of said predetermined range.

4. A method as in claim 2, further comprising the step of:

(e) actuating an alarm signal if said at least one physical measure is out of said predetermined range.

5. A method as in claim 2, further comprising the step of:

(e) recording said physical measure for producing a report.

6. A method as in claim 1, wherein said reference image and said printed image are a single image.

7. A method as in claim 1, further comprising the step of:

(e) communicating said feature of measurement to a distant printing station.

8. A method as in claim 1, wherein said reference image is selected from the group consisting of a prepress digital image and an acquired image.

9. A method as in claim 1, wherein said multidimensional data representation is a multidimensional histogram.

10. A method as in claim 1, wherein said calculation of said multidimensional data representation is according to at least two dimensions, of which at least one is a spatial coordinate, and at least one is a color dimension of a color space.

11. A method as in claim 10, wherein said calculation of said multidimensional data representation is further according to a time dimension.

12. A method as in claim 1, wherein said calculation of said multidimensional data representation is according to at least two dimensions selected from the group consisting of a first spatial coordinate, a second spatial coordinate, an angle, a red color dimension, a green color dimension, a blue color dimension, a cyan color dimension, a magenta color dimension, a yellow color dimension, a black color dimension, an L^* color dimension, an a^* color dimension, a b^* color dimension, an X color dimension, a Y color dimension, a Z color dimension, a L color dimension, a U color dimension, a V color dimension and a time dimension.

13. A method as in claim 12, wherein said at least two dimensions include at least one dimension of a spatial coordinate selected from said first and second spatial coordinates and at least one dimension selected from said color dimension.

14. A method as in claim 1, wherein said clustering of said at least one cluster of data is effected by at least one multidimensional clustering weighting function, each of said at least one multidimensional clustering weighting functions has a predetermined range in each of said dimensions, said clustering is according to at least one rule.

15. A method as in claim 1, wherein said at least one multidimensional clustering algorithm is selected from the group

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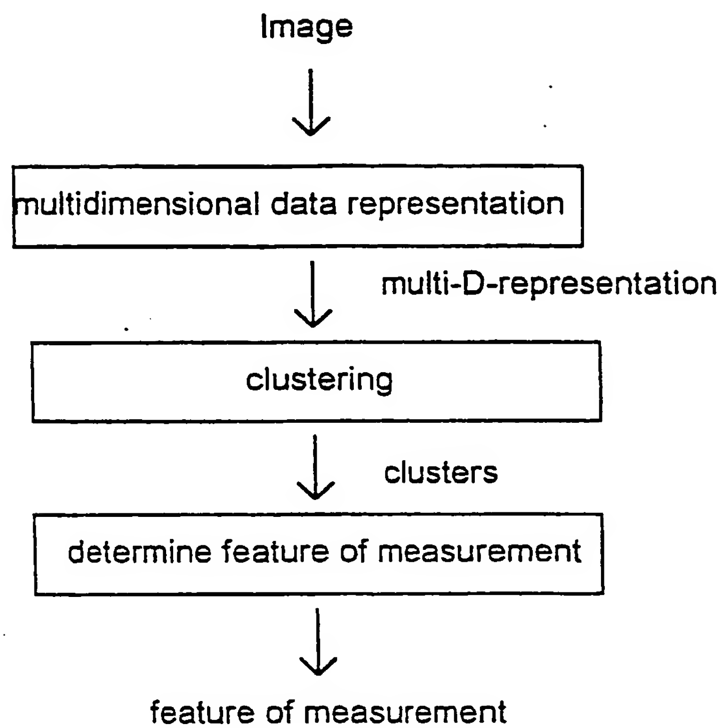
Image
multidimensional data representation
multi-D-representation
clustering
clusters
determine feature of measurement
feature of measurement

FIG. 1

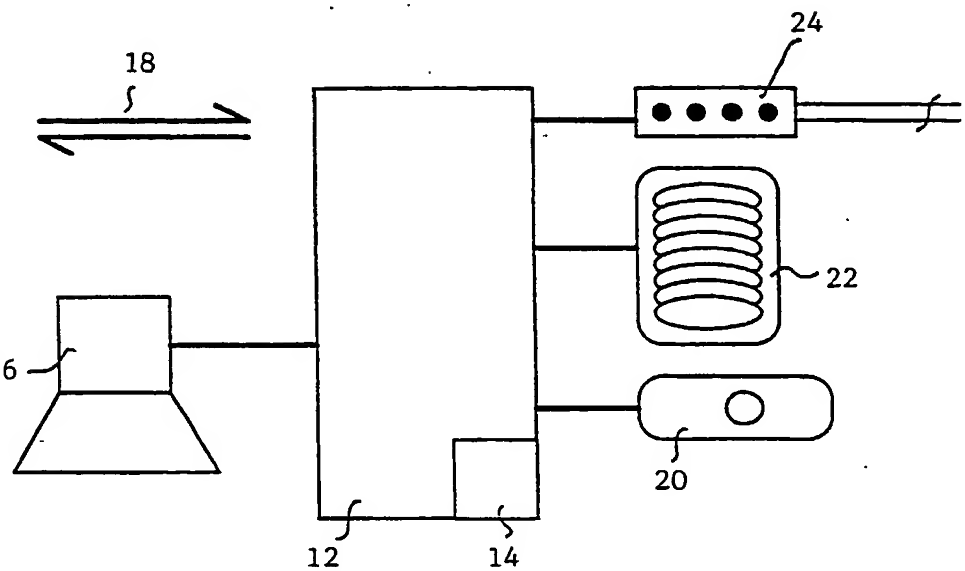

FIG. 3

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